A Smart Multisensor Approach to Assist Blind People in Specific Urban Navigation Tasks

B. Andò, *Member, IEEE*

***Abstract*—Visually impaired people are often discouraged in using electronic aids due to complexity of operation, large amount of training, nonoptimized degree of information provided to the user, and high cost. In this paper, a new multisensor architecture is discussed, which would help blind people to perform urban mobility tasks. The device is based on a multisensor strategy and adopts smart signal processing.**

***Index Terms*—Mobility tasks, sensing devices, smart signal processing, visually impaired.**

I. INTRODUCTION

TO DATE, several aids have been developed to improve the life quality of blind people from the long cane to many electronic devices, as already discussed in [1]–[3]; however, a better understanding of needs and abilities of the visually impaired must be gained to build effective aids. Electronic aids for the visually impaired have not penetrated the market, not least due to consumer diffidence. The reasons for this phenomenon must be sought in the inadequate form of information given by the device, costs, auditory cues (the natural echo is masked), training difficulties, cosmetics, expensive installation, poor dissemination [1].

Problems that result from blindness in mobility are obstacle avoidance and navigation. It is generally accepted that in order to assist blind pedestrians the following information is needed: the presence, location, and nature of obstacles; the texture, slope, and boundaries of the path or travel surface; and spatial orientation.

Researchers at Department of Electrical and Electronic Systems (DIEES), University of Catania, Catania, Italy, are actively involved in research aiming to develop low-cost multisensorial architectures to assist visually impaired people [4], [5]. These solutions, adopting low-cost sensors and dedicated smart algorithms, allow to overcome the limitations of existing technologies, which are really expensive, unsuitable for practical use, and usually give information in which redundancy is not optimized. Activities aiming to measure the performance of the proposed devices are also being carried out. In the following sections, some results concerning a device supporting mobility of visually impaired, already announced in [5], are given.

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The author is with the Department of Electrical and Electronic Systems (DIEES), Department of the Engineering Faculty of the University of Catania, 95125 Catania, Italy (e-mail: bruno.ando@diees.unict.it).

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Fig. 1. Real view of the multisensor probe with a 5 LED array user interface.

The device uses a multisensor architecture and quite complex smart postprocessing to provide the user with information useful to perform urban mobility tasks, such as human detection and walking in crowd conditions. Of course, the inner user ability and skill to perform that specific task remain a key point and the device developed would just improve the user confidence without substituting the user feelings. The level of incremental value the device has over a long cane resides in the contact less operation, while as respect to other electronic travel aids it produce a easy-to-interpret codification of the degree of alert in performing the considered mobility task which should encourage the user in using electronic aids.

II. OVERVIEW OF THE DEVICE ARCHITECTURE

The device is made of two units, the multisensor probe and the processing unit. The multisensor probe has been implemented by a sonar module and an infrared motion sensor, while the processing unit includes electronics for sensors, a microcontroller architecture for signal elaboration, and a user interface notifying the user with information useful to perform the mobility tasks. Real views of the packaged prototype are available in Fig. 1 and in [5].

The sonar module is the MS6501 using Polaroid electrostatic transducers. This is a low-cost device assuring good performances in a range of 10 m with a nominal accuracy less than 2%. This module is used to provide information about both target distance and velocity by two successive measures. The Napion MP sensor, by Matsushita Electric Work, Osaka, Japan, was also included in the probe. It is a passive infrared sensor which detects changes in infrared radiation occurring when there is

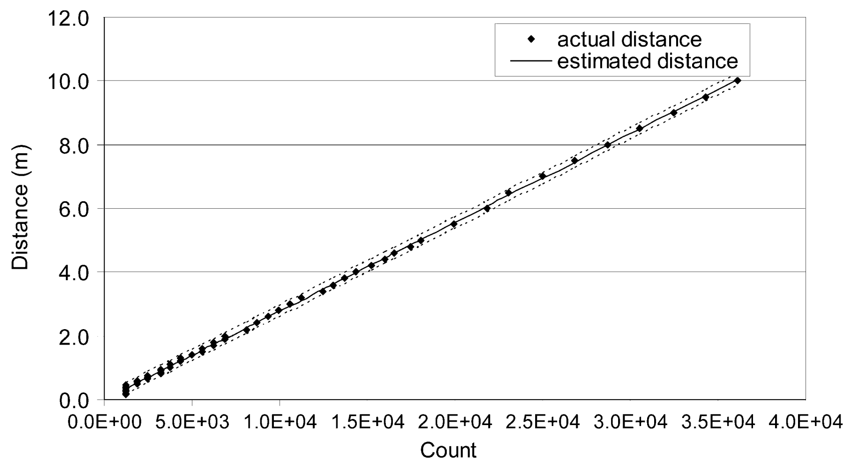

Fig. 2. Characterization of the sonar module for distance measurement. Actual distances (symbols), the estimated model (solid line), and the tolerance band (dotted lines) are reported.

movement by a person which is different in temperature from the surroundings.

Signals from the sonar module and the Infrared sensor are conveyed to the microcontroller unit. The adopted microcontroller is the ST52F513 belonging to the ST-FIVE family, by STMicroelectronics, Geneva, Switzerland, including a Fuzzy core. Suitable algorithms have been implemented by the visual-five developer tool by STMicroelectronics to perform sensors management and signal elaboration.

Fig. 2 shows results for the characterization of the sonar module as distance sensor [6]. An uncertainty of approximately 10 cm was estimated [7].

By using two successive distance measurements, d1 and d2, the object velocity is also estimated, according to the following expression, where fclock is the frequency of the microcontroller timer. An uncertainty of 1.75 m/s for the velocity estimation has been obtained, propagating the uncertainty on distance measurements [7].

Dedicated routines implemented on the microcontroller provide the user with information about the status of the environment (in the form of attention levels which assumes different meaning on the basis of the action to be performed). In particular, the algorithms implemented allow to perform human detection and walking in crowd conditions. Actually, the user can choice for receiving either a continuous flow of information (which can be suitable in the crowded walking mode) or on request information (which can be desired in the human detection mode).

Actually, a degree of ready-to-go (or alert) is given which is directly related to the possibility to perform the task in a safe way. Only five levels of alert have been used to reduce complexity of information provided to the user. This choice is motivated by the need to provide the user with a easy-to-interpret codification of the safety degree in performing a specific task. The user in hence not required to combine different information such as distance and velocity of the target to take a decision on the suitability to perform that specific mobility task. He can base his decision on a degree of alert which is opportunely derived by a smart processing of sensors signal. In the prototype developed attention levels are given by a 5 light emitting diode (LED) array included in the sensor probe, as shown in Fig. 1.

Data fusion algorithm			
Crowded walking algorithm			
	$DV \leq 0$	$0 < Dv \leq v_1$	$Dv > v_1$
$d \leq d_1$	5	4	5
$d_1 < d \leq d_2$ & H=1	5	2	4
$d_1 < d \leq d_2$ & H=0	5	5	5
$d > d_2$	3	1	3
As an example, levels of alert can be interpreted as follows: 1=free to go, 2=move slowly, 3=reduce speed, 4=stop, 5= move to avoid collision.			

Fig. 3. Rules implementing the data fusion algorithms for the crowded walking mode; di and v1 are suitable thresholds estimated on the basis of experiments performed with the device, H is the status given by the infrared detector: $\mathrm{H} = 0$ stands for "no human detected" and $\mathrm{H} = 1$ stands for "human detected."

In the human detection mode, only the information given by the infrared detector is used to notify the user for the presence of people in the detection range of the device.

Rules implementing the crowded walking algorithm are schematized in Fig. 3. As it can be observed data coming from the infrared detector (which notifies for the presence of people in the detecting regions of the device) and information on target distance and relative velocity between the user and the target are used. Suitable distance and velocity thresholds have been fixed on the basis of literature data on human speed and on the basis of real experiments performed during the device characterization. The crowded walking algorithms aims to reduce the need for user movement to avoid obstacles, except when a high-speed target or an inanimate object is detected on the user path. Examples on how the user can interpret alert levels are given at the bottom of Fig. 3.

Although the device allows the communication with any other kind of interface (acoustic, vibratory, tactile) during this preliminary development phase, the LED array interface results really efficient. In particular, during the test phase of this preliminary prototype an expert joined the user adopting the device to communicate him the attention level (provided by the device and visible by the LED interface), making tests independent on the user ability to properly associate the codified information with the actual attention level. It must be stressed that only five levels of alert are used to optimize the degree of information and to avoid complex training. A critical task, such as independent travelling, requires a short time to interpret codified information, decide how to respond, and then respond appropriately. Moreover, past experience with electronic travel aids suggest that devices are abandoned if inordinate amount of experience is needed to give the device value. A LED matrix array codifying estimations of distance, velocity, and human presence, has been included in the processing unit for the sake of developer convenience.

Experimental surveys were performed by developers to set rule sets and thresholds for distance and velocity while the skill of blind people with expertise in the field of orientation and mobility was exploited to optimize the way to codify the information provided from the sensing devices.

Three series of tests were organized, one for each working mode. In the walking mode, tests were oriented to perform tasks such as obstacle avoidance.

III. Preliminary Results and Conclusion

The device developed was tested by end-users to assess the device reliability in terms of capability to detect obstacles and approaching targets.

Experiments were conducted both by experts and blind people in supervised mode. Of course, due to the hazard in performing tests in unstructured environment we decided to implement such surveys in a secure area just to explore the device behavior and to demonstrate its suitability in helping blind people. This experimental survey has to be considered as a preliminary qualitative test aimed to assess the device reliability and to estimate the quality and the degree of information provided to the blind user. To that aim, the user is not asked to interpret the codified information given by the device and to convert it to the actual level of attention (actually the supervisor communicate him the level of alert given by the device, from 1 to 5, and he must only decide the action to be performed at that level of alert.

A valuable behavior of the device was evidenced in the walking mode, especially for young and medium age people. Moreover, on the basis of user feedbacks it can be affirmed that the averaged comments were positive especially for what concerns the simplicity of the provided codification and fast training. Of course, the proposed codification is just an example on how the system can work.

In a future version of the device, a tactile interface will be included. This will allow a deep and rigorous characterization of the device in order to estimate quantitative indexes assessing the performances of the multisensor approach. Direct measures of indexes strictly related to the task to be accomplished by the device (such as people and obstacle avoidance) as well as expert judgments, self-reports on the quality of performance, and estimates of personal satisfaction will be also taken into account.

Work in progress will also focus on the optimization of the data fusion algorithm (which could exploit the facility of the microcontroller adopted to implement a Fuzzy data-fusion paradigm instead of a set of crisp rules), the possibility for the user to choose the degree and the redundancy of the information provided by the device and the possibility to extend the multisensor approach to other purposes.

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B. Andò (M'96) received the M.S. degree in electronic engineering and the Ph.D. degree in electrical engineering from the University of Catania, Catania, Italy, in 1994 and 1999 respectively.

From 1999 to 2001, he was a Researcher with the Electronic Measurement Group, Department of Electrical and Electronic Systems (DIEES), University of Catania. In 2002, he became an Assistant Professor with the same staff. His main research interests are sensors design and optimization, advanced methodologies, and smart transducers for bio-application, sensing architectures for impaired people, smart materials, and advanced nonlinear techniques such as stochastic resonance and dithering applications. He has coauthored several scientific papers and books.